Electrolysis in Underground Structures

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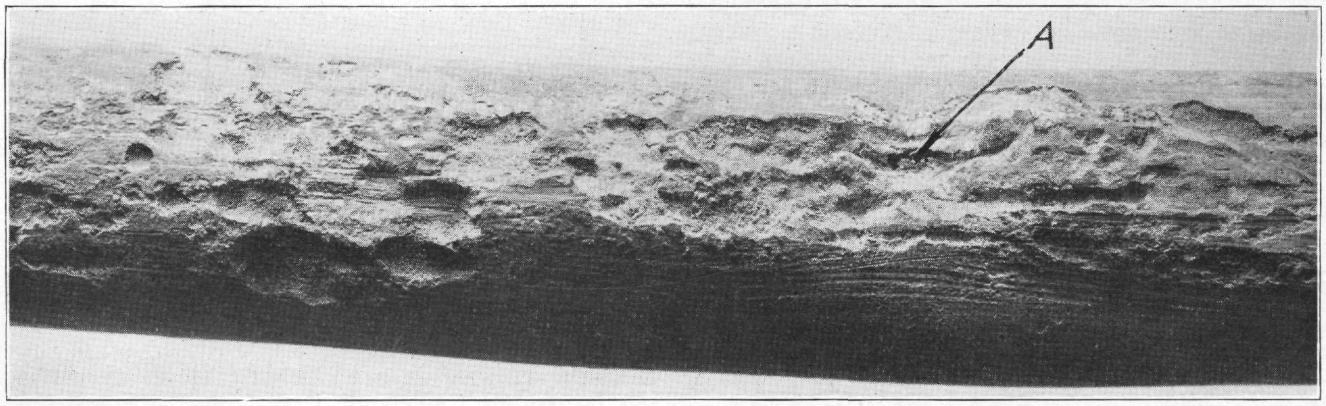
Cause and Effect of Electrolysis.

Electrolysis is defined as the chemical decomposition resulting from the flow of an electric current between conducting terminals called electrodes. If the anode by which the current enters an electrolyte consists of a metal which can combine chemically with the anions set free by the electrolytic action, then this anode will be decomposed or corroded. This electrolytic corrosion of an anode is what will be referred to hereafter as electrolysis.

In the electrolysis of gas and water pipes, cable sheathes, and other underground metalic structures, the moisture of the soil with its dissolved acids, salts and alkalis is the electrolyte, and the pipes and cables are the electrodes. Electrolytic corrosion of the underground structures occurs when stray electric currents leak from the underground metallic conductors into the earth, the tends to leave the underground structure is known as a positive area, and likewise a region where the underground systems are at a lower potential with respect to the rails is called a negative area.

The amount of metal displaced by electrolytic corrosion is proportional to the product of the current strength and time which it flows and also depends upon the frequency of the current. In the case of iron pipe, the amount of corrosion in wet soils will be about 20 pounds per ampere per year; similarly for lead pipes the corrosion will also vary with the percent of moisture and the nature of the soil. The amount of metal displaced increases with decrease in frequency, reaching a maximum in the case of direct current. The damage is not always proportional to the weight of the displaced metal, as the current may be discharged locally producing the phenomenon commonly called pitting. In this manner a small



The above photograph shows a portion of a 1 1-4 inch telephone lead cable sheath which has been badly pitted by electrolytic action. At a point "A" it can be seen that the sheath has been eaten completely away; this condition renders the cable useless, for it allows moisture to enter, which destroys the insulation of the cable pairs

metal being carried into solution by the current flow, the presence of these stray currents in the underground structures is explained as follows:

In the simplest arrangement of electric railways using the tracks as return conductors, the rails are connected to the negative terminal of the generator at the power station or the substation, and the current returns to the station through the rails. Where these rails are in contact with the ground, part of this current will shunt through the earth and through underground metallic structures; this shunted current will leave the rails in districts remote from the power house, and will return to the rails in the neighborhood of the power station.

It is in this latter region where the current is leaving the pipes and cables that the damage to the underground structures occurs, for the electrolytic action produced by these currents results in corroding the underground metallic parts of the underground system. A district such as this where the potential of the underground conductors is above that of the rails, and where current hole may be eaten entirely through the pipe, thereby destroying its usefulness, while the average corrosion over the surface of the pipe may be relatively small.

A good specimen of a cable destroyed by electrolytic corrosion was obtained from Akron, O. Photograph of this cable on page 15 shows clearly the serious damage done by pitting. In several places the cable has been completely eaten through.

METHODS OF PREVENTION AND MITIGATION APPLICABLE TO RAILWAY NEGATIVE RETURNS

The Double Trolley System.

The ideal method for preventing electrolysis is the use of the double trolley system, since with this method there is a complete insulated circuit and the danger of electrolysis is almost entirely eliminated, the small leakage current that flows being of no practical consequence. The main disadvantages of this method are (1) the high first cost due to double weight of copper in the trolley, and (2) complexities of construction and resulting high maintenance.

Insulated Negative Feeder System.

Since the drop in potential in grounded rails is the cause of the flow of stray current through the earth, the escape of stray currents will be reduced in the proportion that the drop in the rails is reduced. It is therefore desirable to use heavy rails of high electrical conductivity, and to maintain these rails perfectly bonded, so that they form continuous low-resistance conductors. The next important consideration is to limit the distance from the supply station to which this station delivers direct current power, so that the current is not returned through an excessive length of the track; this is usually accomplished by the use of a number of distributed sub-stations. Finally, the current should be removed from the rails by means of insulated return feeders connected to the rails. These feeders draw current from the rails at such points as are necessary to avoid both an excessive potential in the tracks and through earth and an excessive total voltage drop in the tracks. Where it is necessary to bring current back from a distant point in the tracks, it is sometimes more economical to employ a negative booster in series with a return feeder of small cross section, than to make this feeder of cross section large enough to drain the required current from the tracks at the distant point. It may also be necessary to install resistances in short feeders. With such insulated tracy return feeders, part of the voltage drop is removed from the rails and is transferred to the insulated return feeders, from which current cannot leak to the ground. With this arrangement of insulated return feeders, the rails may be utilized as return conductors to the extent that the potential gradients and total track drops do not exceed safe limiting values.

Balanced Negative Feeder System.

In the balanced insulated negative feeder system, instead of connecting the tracks directly to the negative bus bar and depending upon the tracks and such copper conductors as may be in parallel with them to return the current to the power house, the connection at the power station is either removed or given a suitable resistance, and insulated feeders with properly proportioned resistances are run from the negative bus bar to the various points on the tracks so that these points of connection are all at the same potential with reference to the negative bus bar. The advantage of this method is that high current densities and consequently high potential gradients ,volts drop per given length of rail) in rails may be avoided to any given degree. A combination of this system along with proper bonding of the tracks is a very satisfactory method of avoiding current leakage from the tracks. Electrolysis conditions in England have been practically eliminated by a stringent application of this method.

METHODS OF PREVENTION APPLICABLE TO UNDERGROUND STRUCTURES

In an effort to reduce the possible damage to underground systems of pipes and cables many methods of mitigation have been proposed and tried. In some cases these have proved saitsfactory to a certain degree while in others they have failed completely. We shall endeavor to briefly discuss a few of these methods pointing out their relative advantages and disadvantages.

Insulating Coatings.

A method which at first thought seems feasible is to coat the underground structures with some insulating compound, thus preventing current leaking from the undergrounds into the earth. The great disadvantage of this method is the difficulty in obtaining a compound that will remain on the pipes or cables any length of time. Whenever a small portion of this insulating coating is removed in any way, the entire damage takes place over a comparitively small area causing injuries that may result in a failure of the system.

Insulated Joints.

Current flow on pipes or cable sheathes can be practically prevented by using a sufficient number of insulating joints. A pipe line laid entirely with insulating joints has a comparatively high resistance and cannot pick up current in an extensive negative area and discharge it in a restricted positive area, which is generally the cause of the most serious electrolytic danger. It is sometimes possible to use comparatively few insulating joints to break up the electrical continuity of a pipe line, and so to protect the line from electrolysis. Such joints however, must be installed only after careful tests have shown that the current is not likely to shunt thru the earth around them and thus incur a condition worse than the previous one. This effect depends largely upon the potential gradient through earth, and also upon the electrical resistivity of the soil.

Drainage Wires.

This system consists essentially of connecting copper conductors at suitable points to the pipes or cable sheaths where they have a tendency of becoming positive to the earth; the conductors will then carry the current from the above structures instead of allowing it to leak off directly to the earth. These conductors may either be direct bonds between the underground and track or may be special feeders running out from the negative bus bar at the power house. Such bonded connections however, should only drain enough current from the cable sheaths to render them at the same potential or slightly negative with respect to neighboring structures.

Methods of Making Electrolysis Surveys.

In order to determine the extent of the damage that may be done to underground structures by electrolytic corrosion, it is necessary to make a general electrolysis survey. Electrolysis surveys may be divided into three general classes, name, voltage surveys, current surveys and miscellaneous readings.

VOLTAGE SURVEYS

Potential Difference.

As explained above, if there is a difference of potential between the railway negative structure and other underground ysstems, it is important to know the value of the voltage which exists and which conductor is at higher potential, so that the direction and relative amount of the leakage current may be known. These potential readings may be obtained directly by connecting the terminals of a low reading voltmeter to the rail an dto the structures under test, such as cable sheaths and pipes. It is desirable also to obtain the difference of potential between the various underground systems, as often one system because of direct drainage, will be at a lower potential than the neighboring structures, thereby endangering the systems which are at the higher potential. Readings should also be taken between the cable sheath and ground, pipes and ground, rail and ground.

Overall Potential Difference.

The expression "overall potential difference" as used here may be defined as the difference of electrical potential existing between the point of lowest potential in any feeding district and points of approximately highest potential on or near the various branches of the railway system. The importance of obtaining overall potential readings is to determine whether the potential drops exceed a certain definite and relatively low value. Oftentimes city ordinances, designed for the protection of underground structures, specify that these potential differences shall not be greater than a certain value.

Since the points between which the potential is to be observed are quite widely separated, it is convenient to use idle telephone cable pairs for voltmeter leads. Except for distances exceeding seven or eight miles, the error introduced by the r esistance of these pairs is very small and can be neglected.

Potential Gradient.

A potential gradient is the rate of change of potential along a given conductor. It is generally expressed in volts per thousand feet, but this is intended to convey the idea of the rate per thousand feet at any point and not that one thousand feet is the exact length to be employed. All potential measurements between two points on the track or between two points in the earth over distances materially less than the extremes of the power house feeding area come under the head of potential gradients. These readings can be made in a similar manner to overall potentials by using idle cable pairs.

Current Measurements.

The amount of current carried by underground structures is often so closely related to the total extent of damage produced that a knowledge of its magnitude is often very desirable. Among the various conductors in which current measurements are necessary are copper feeders, railway rails, cable sheaths and gas and water pipes. In the case of copper feeders where fuses are in the line, an easy method of current measurement is available, for a standard shunt may be inserted in place of the fuse, and the amount of current determined by the voltmeter reading. A fairly accurate estimate of the current flow in lead cable sheaths can be obtained by observing the fall of potential along a definite length of cable and dividing this by the known resistance of that length. The current in water and gas pipes can be measured in a similar manner, where the resistance of a unit length of pipe is known.

When heavy currents are flowing in gas pipes, there arises a danger of arcing at the points where the pipe line and its connection are opened, for the arc may ignite escaping gas. Large currents in pipes are also accompanied by the danger of corrosion on the positive side of the high resistance joints. In order to guard against these and other dangers it is important to keep the current flow in pipes at as low a value as practicable; but in the case of lead sheaths, the resistance is very low and since the cable is a continuous conductor, large amounts of current may be drained by them without endangering the cable.

Oftentimes twenty-four hour charts are made with a recording ammeter, showing the variation in amounts of currents flowing in cables and copper feeders for the different periods of the day. From a comparison of these charts and power house load curves, it is possible to determine the proportion of the total power returned by the cables.

Miscellaneous Measurements.

Depending upon the local conditions, it becomes necessary at times to make various electrical measurements upon tracks and underground systems. For instance if it is contemplated to install a pipe drainage system, this should not be done until it has been definitely determined that there are no high resistance joints in that portion of the line in which heavy currents would be likely to flow; these high resistance joints are most conveniently located by means of potential gradient measurements along the pipes.

Tests upon tracks are often important in locating the cause of any bad electrolysis conditions that may have been previously encountered and also to serve as a guide in maintenance of track bonding and return feeders. Track tests usually consist in measuring the current density in the track at various points.

In order to determine what overall potential drops may safely be permitted in the track return, it is very desirable to know the average resistance of the leakage path between railway track and surrounding earth. It is evident that if the resistance of the leakage paths is very high it will be safe to allow higher potential drops on

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VOLTAGE SURVEY

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the track than if the leakage resistance were low. One method of determining this resistance consists of inserting insulating joints in the track at two points one thousand feet or more apart; then at night when no traffic is on the line, a low voltage battery is applied between the isolated section of the track and a suitable earthed terminal. When this connection is made the current flowing from the battery to the isolated section of the track must practically all pass off through the track roadbed in this section, and this current is measured simultaneously with the potential difference between the track and a second earth terminal which is quite remote from the earth terminal which is carrying the current of the battery. The resistance of the leakage path between the isolated track section and the ground is then calculated from the ammeter and voltmeter reading.